United States
Department of
Agriculture

Forest Service

**Technology &
Development
Program**

2400—Forest Management
April 1999
9924 1202—SDTDC

Trigger Pull Force Evaluation of Three Manual Tree Marking Paint Guns

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by
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April 1999

ACKNOWLEDGEMENTS

Industrial Biomechanics, Inc., Greensboro, NC, conducted the test under contract with the USDA Forest Service. Industrial Biomechanics also provided a report of their testing and supporting data that was used in the preparation of this document.

A special thanks also goes to the following people. Without their contributions this report could not have been written.

Don Hunt Business Unit Director, Force Measurement Systems, John Chatillon & Sons, Inc. for the test stand and assistance in the mechanical testing of the three guns.

Mary Bergeron, MS, L.P.T.; Jeff Mahoney, R.P.T.; Patrick Huff, Engineering Student; all from The Therapy Center, Knoxville, TN for the electromyography testing and reports.

BACKGROUND

Hand operated paint guns are routinely used in the Forest Service for tree marking. The paint gun is designed to screw onto the top of a one-quart can of tree marking paint. Several brands of paint guns can be used with Forest Service tree marking paint.

More than 170 Forest Service ranger districts responded to a simple survey sent by San Dimas Technology and Development Center asking for information on the types of guns used in the field and if there have been any paint gun related problems. The results of the survey revealed that the Nel-Spot (64%) is the most used manual paint gun. The Trecoder (25%) was second, followed by the Idico or Duz-All (3%). Powered guns comprise the remaining eight-percent. The most common problems associated with manual gun use were nozzle clogging (61%), hand/wrist pain (26%), poor cold weather performance (11%), and hard trigger pull (8%). Additional information on the paint gun survey can be obtained from the *Tree Marking Tricks of the Trade* Tech Tip (9724 1301—SDTDC).

The three manual paint guns typically used by a paint crew are similarly designed. These guns are not powered and rely on the operator's trigger squeeze to propel the paint. The Nelson has a short trigger for a two-finger pull; the other two models have a long trigger for a four-finger pull.

OBJECTIVE

The objective of this study was to measure the pull force required to engage each of the three most frequently used manual paint guns in the Forest Service. These guns are used to spray USDA Forest Service paint onto trees at shoulder level and at the base of the tree a few inches from the ground surface.

METHODS

Paint Gun Testing

Measuring the actual trigger pull force on a manual gun is complicated because of the different trigger designs, rates of pull, and pressures required to propel the paint. The methods used in this test attempt to eliminate some of these variables. Each of the three guns (Trecoder, Nel-Spot, Duz-All) shown in figure 1 was tested mechanically for pull force with and without the paint can attached. A Chatillon DFGHS-R-100 digital force gauge with a remote load cell attached, figure 2, was used to measure the forces with and without the resistance of the paint, figure 3. The force gauge and the load cell were connected to a Pentium laptop computer through the RS-232 port. Data acquisition software, Data Stream, by Chatillon was utilized to collect the data both from the manual load cell testing, as well as the test stand.

Figure 1—Trecoder, Nel-Spot, and Duz-All manual paint guns.
Note: The Idico and Duz-All paint guns are identical.

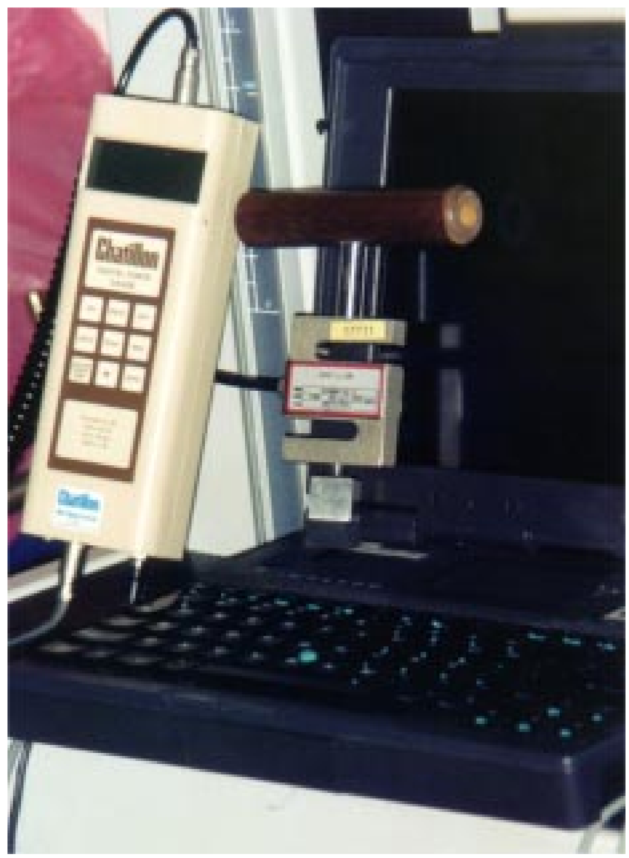


Figure 2—Chatillon DFGHS-R-100 digital force gauge.

Figure 3—Testing a Nel-Spot paint gun with remote load cell while attached to paint can.

Electromyography (EMG), a technique that allows measurement of muscle activity, was used to determine muscle activity in the muscles most important in the paint gun task; the wrist flexors, the wrist extensors, some hand muscles (interossei) and selected shoulder muscles.

Figure 5

Methods Perspective

Problems and complaints about this human tool interaction are only partially explained by mechanical methods used to test the guns. The other part of the equation that must be examined is the human side. Forest Service tree markers have complained about pain of the hands and wrists caused by what they feel is the excessive force required and the number of repetitions needed to accomplish the task. Whenever ergonomists determine the relationship of soft tissue complaints to a job the standard equation, as shown in figure 4, is used.

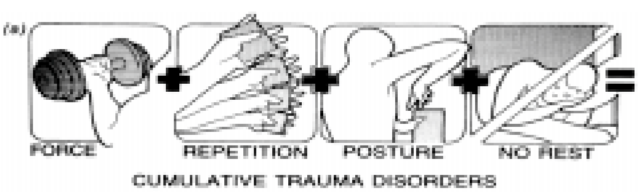


Figure 4—Standard equation to determine cumulative trauma disorders.

How are the components of this equation determined? The methods described previously revealed the forces required to engage each gun; the repetitions can be calculated from data or viewed from video taken in the field under actual working conditions. The postures are easily observed from the video or a simulation. The unknown that remains is what does the task/tool require of the muscles to elicit and maintain the postures?

EMG measures electrical activity in voluntary muscles in the same way electrocardiography measures electrical activity of heart muscle. EMG data were collected using a Noraxon surface EMG telemetry system (Noraxon™, Phoenix, AZ) with bipolar silver-silver chloride surface electrodes. Norquest software, also by Noraxon, was used to process the data. Surface EMG and associated signals were measured and processed in a belt-worn transmitter using technology that allows more artifacts free results. Telem-etry allowed the data to be transmitted from the test subject via radio waves to a computer-connected receiver.

Figure 6

Using this technology, the subject was able to move freely in a manner that resembled the movements of persons who use paint guns for the Forest Service. One male subject whose maximum grip strength was 80.5 pounds (358 N) performed the tests. The subject performed 9-11 trigger pulls at both shoulder and below shoulder level using each of the three guns. See figures 5 and 6.

RESULTS

Force Applied Without Paint Resistance

The Duz-All gun required less force when each gun was affixed to a ring stand and manual force was measured with a remote load cell on a specially adapted handle. The table below shows peak force by gun type without a paint can attached. The raw data for this test are contained in appendix 1.

Table 1—Manual trigger pull force without paint.

Gun Type	Peak Force in Pounds (N)
Nel-Spot	17-20 (76-89)
Trecoder	18 (80)
Duz-All*	< 10 (<44)

Force Applied at a Constant Rate

When the force is applied at a constant rate, the test results shown in table 2 confirm the previous readings of the trigger pull force without paint. The trigger pull rate in this test was held constant to eliminate one of the variables. The Duz-All consistently registered the lowest trigger pull force. The test data are included in appendix 2.

Table 2—Trigger pull force at a constant pull rate without paint.

Gun Type	Peak Force in Pounds (N)
Nel-Spot	12-17 (53-76)
Trecoder	15-17 (67-76)
Duz-All*	8 (36)

Electromyography

The electromyographic tests of muscle activity corroborated the mechanical tests; the Duz-All required less force. EMG test results are shown in table 3. Variances from the general observation that the Duz-All required less trigger force are mostly explained by the muscle activity when the gun is pointed downward, to keep a protrusion on the back of the gun from digging into the hand. Duz-All's requirement of less force at shoulder level gun engagement became somewhat of a liability when the subject lowered the gun, even though the forces remained generally lower than the forces with the other two guns. When the gun is lowered the "softer" spring mechanism does not provide sufficient counter force to the force of gravity on the can of paint. Due to the inadequate counterbalance, the subject found the small metal protrusion on the back of the Duz-All dug into the thumb web-space as the gun was lowered (dramatic on the video) to simulate marking at the base of the tree. This is not a difficult design problem to correct in light of the other attributes of the gun: light in weight, four-finger trigger design, wide trigger to allow wide force distribution. The Nel-Spot data are not included in the table because the gun malfunctioned and would not spray the paint.

** Duz-All is identical to Idico paint gun.*

Table 3—Muscle activity with gun use at shoulder and below shoulder level averaged peaks of activity in microvolts.

At Shoulder Level	Duz-All*	Trecoder	Below Shoulder Level	Duz-All*	Trecoder
Wrist Extensors	461	550	**Wrist Extensors**	410	547
Wrist Flexors	435	777	**Wrist Flexors**	588	634
Ant. Deltoid	402	305	**Ant. Deltoid**	175	390
Triceps	59	62	**Triceps**	73	71
Upper Trapezius	94	23	**Upper Trapezius**	71	155
Lower Trapezius	41	36	**Lower Trapezius**	31	41
Pectoralis	272	211	**Pectoralis**	175	316
Interossei	235	444	**Interossei**	235	403

Force Applied With Paint Resistance

During these tests the Nel-Spot gun which malfunctioned in the EMG test was replaced. The trigger mechanism of the replacement Nel-Spot gun malfunctioned during this test with the paint can attached. The raw data for tests with the paint can attached are contained in appendix 3. These data clearly show the trigger malfunction. Peak force data with paint can attached and filled with Forest Service Type III low volatile organic compounds paint are shown in table 4.

Table 4—Manual trigger pull force with Forest Service Type III paint.

Gun Type	Peak Force in Pounds (N)
Nel-Spot	40-45 (178-200)
Trecoder	28-38 (125-169)
Duz-All*	15 (67)

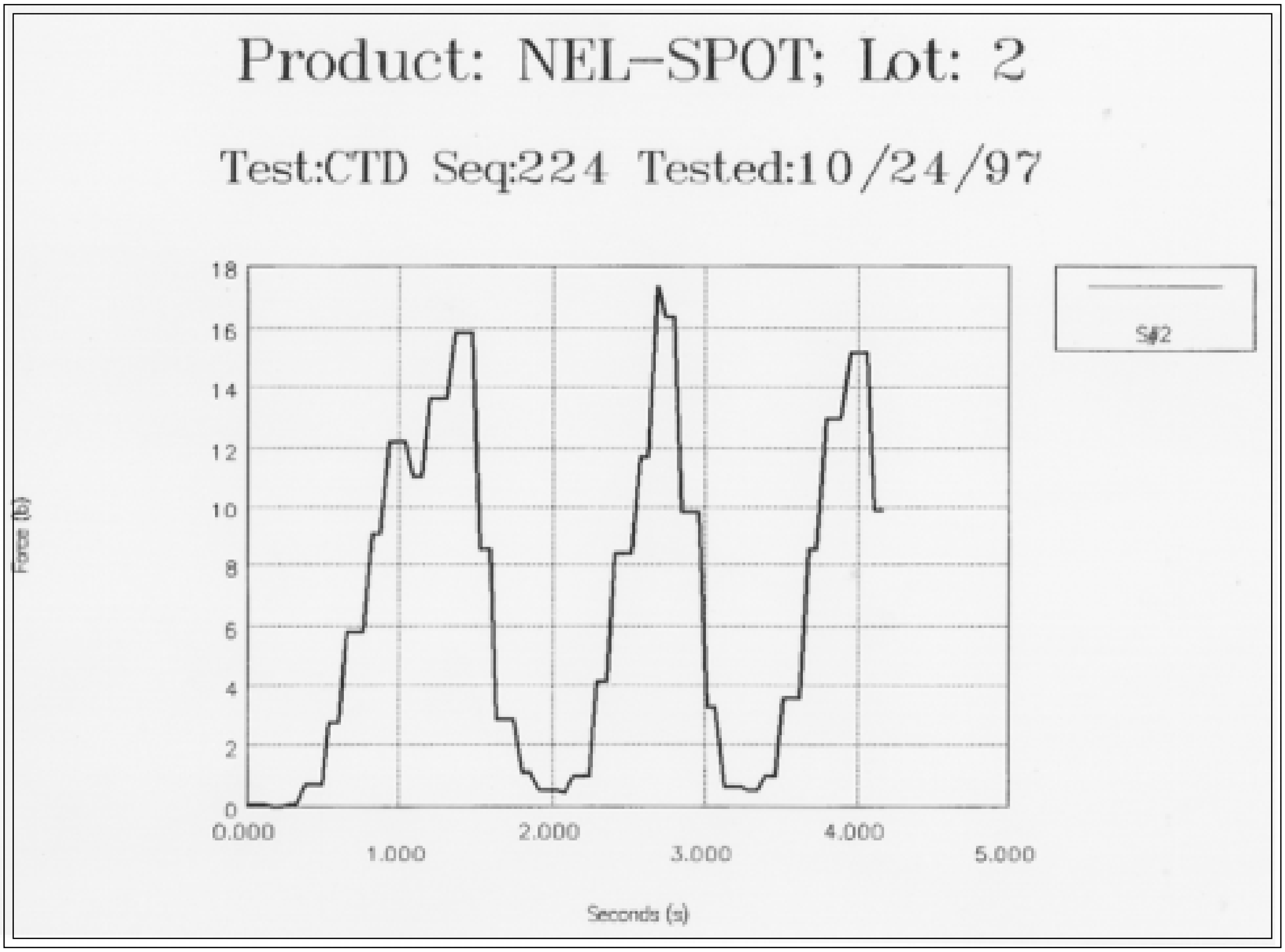
** Duz-All is identical to Idico paint gun.*

CONCLUSION

The Duz-All requires less force than the Trecoder or the Nel-Spot based on the data from all of the tests listed and discussed. These three guns were tested using Type III paint. Additionally, approximately 20 percent increase in grip force should be added when gloves are used with any of the guns. This additional grip force is an accepted rule of thumb in ergonomics. The Duz-All is less stressful to the wrist and hand from force required. Using the same guns with water clean-up paint would intuitively require less pull force; however, the relative spread of values should be similar.

APPENDIX 1

Manual Application of Force to Triggers Without Paint Force Peak Data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Force (lb)
Seconds (s)
S#2
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2
4
6
8
10
12
14
16
18
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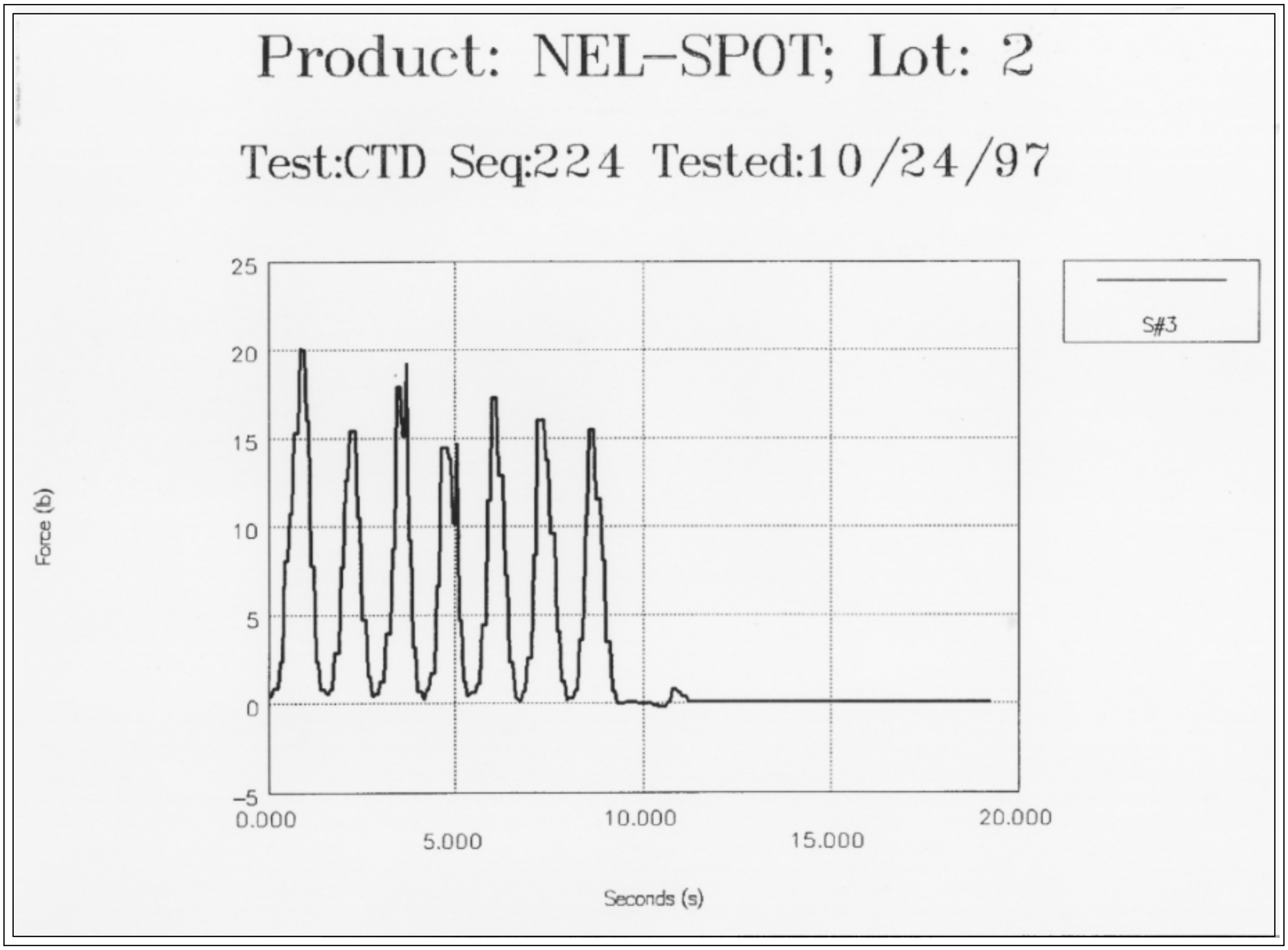
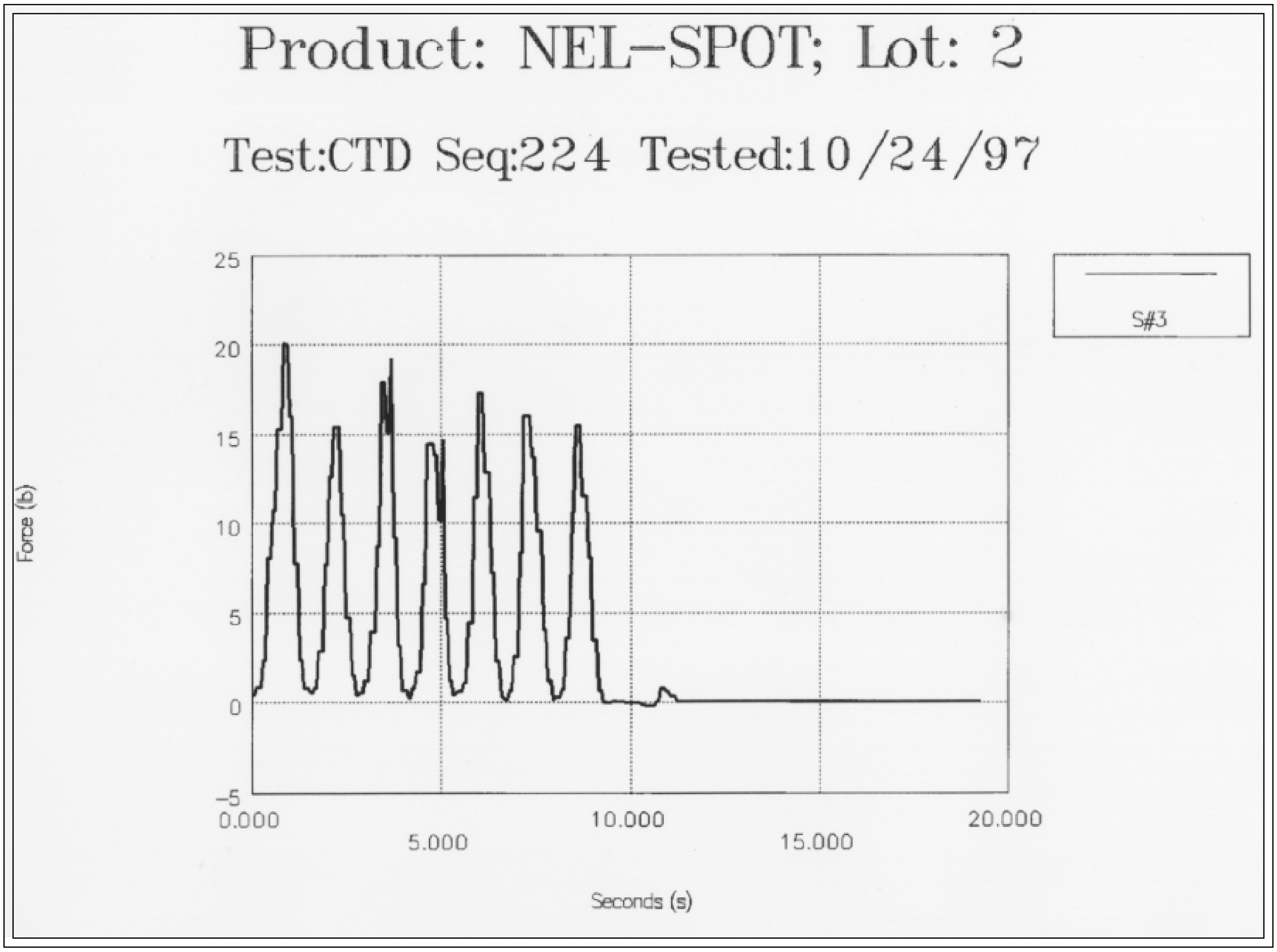
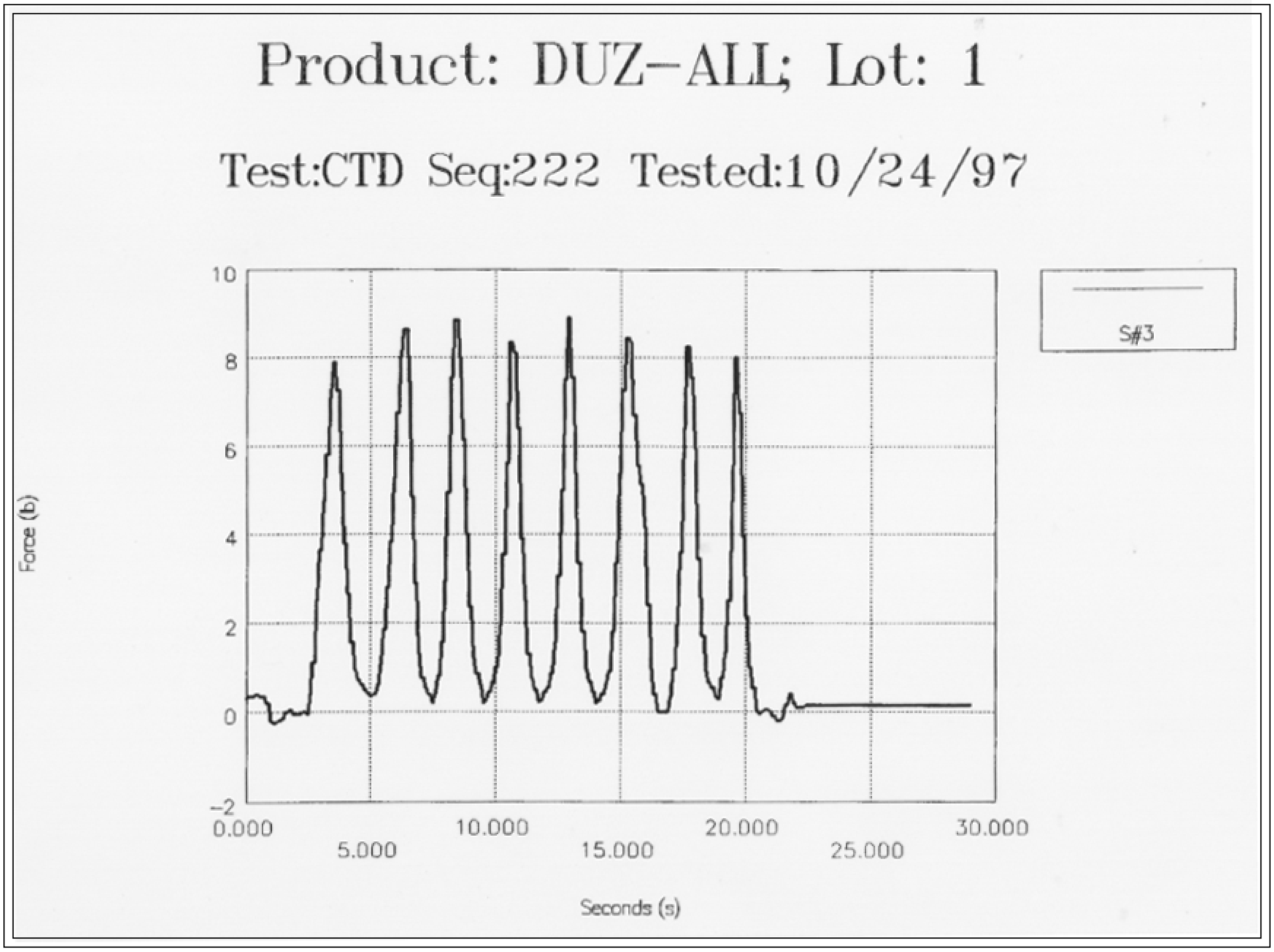
1.000
2.000
3.000
4.000
5.000



Product: NEL-SPOT; Lot: 2
Test:CTD Seq:224 Tested:10/24/97
25
20
15
10
5
0
–5
Force (lb)
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#3



Product: NEL–SPOT; Lot: 2
Test:CTD Seq:224 Tested:10/24/97
25
20
15
10
5
0
–5
Force (lb)
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#3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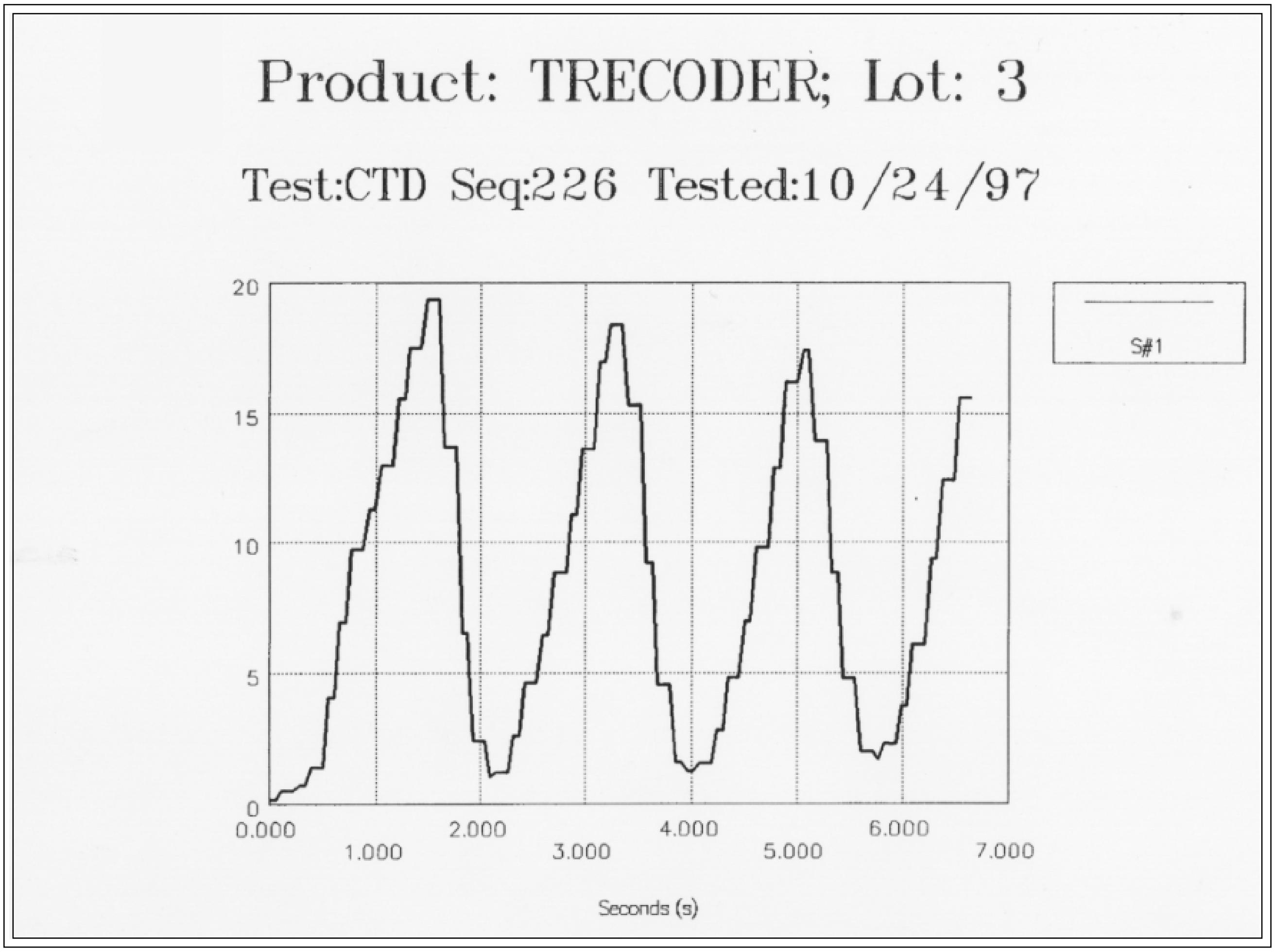
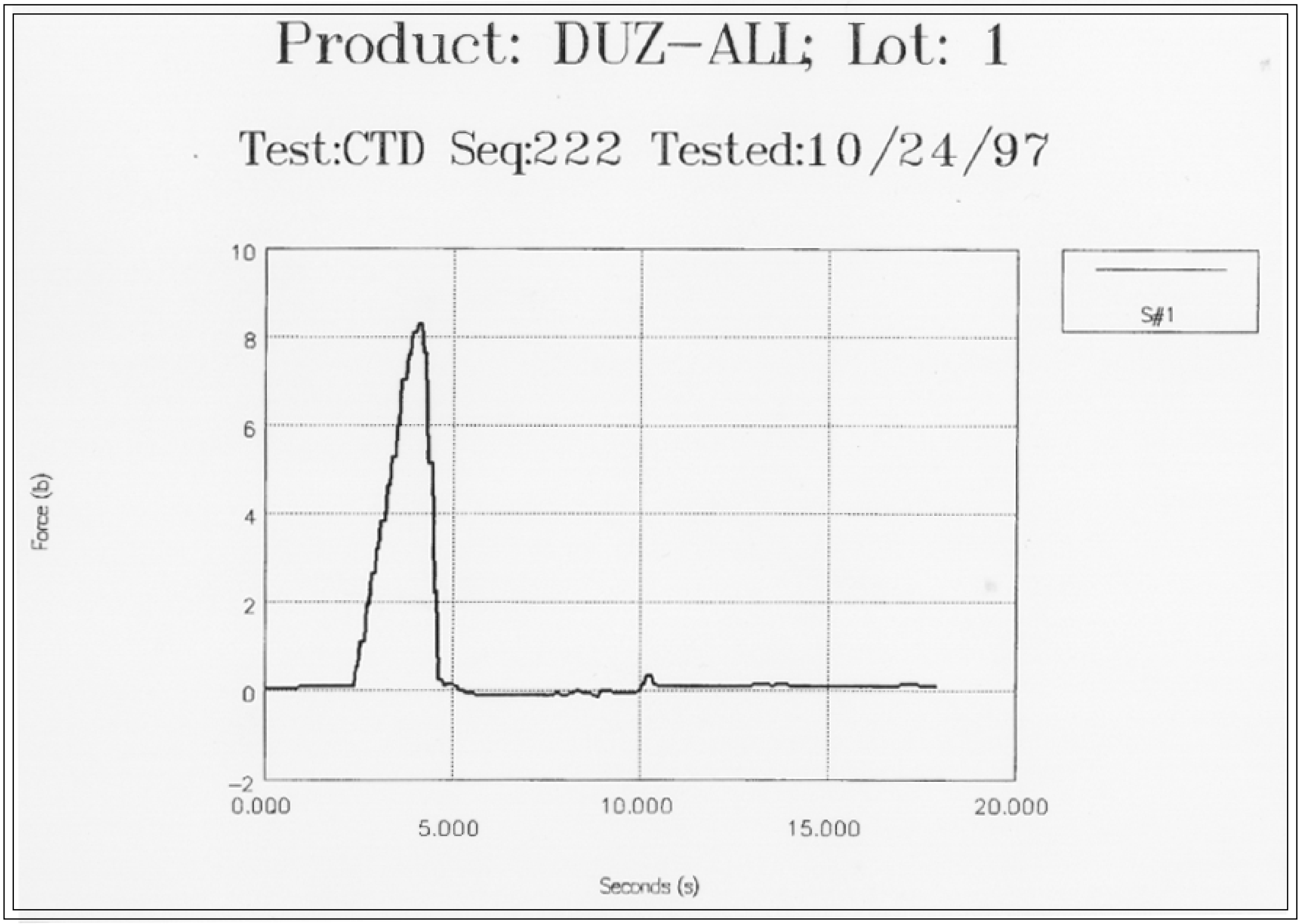
Test:CTD Seq:222 Tested:10/24/97
S#3
Force (lb)
Seconds (s)
10
8
6
4
2
0
-2
0.000
5.000
10.000
15.000
20.000
25.000
30.000



Product: TRECODER; Lot: 3
Test:CTD Seq:226 Tested:10/24/97
20
15
10
5
0
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
Seconds (s)
S#1

APPENDIX 2

Test Stand Application of Force to Triggers Without Paint Force Peak Data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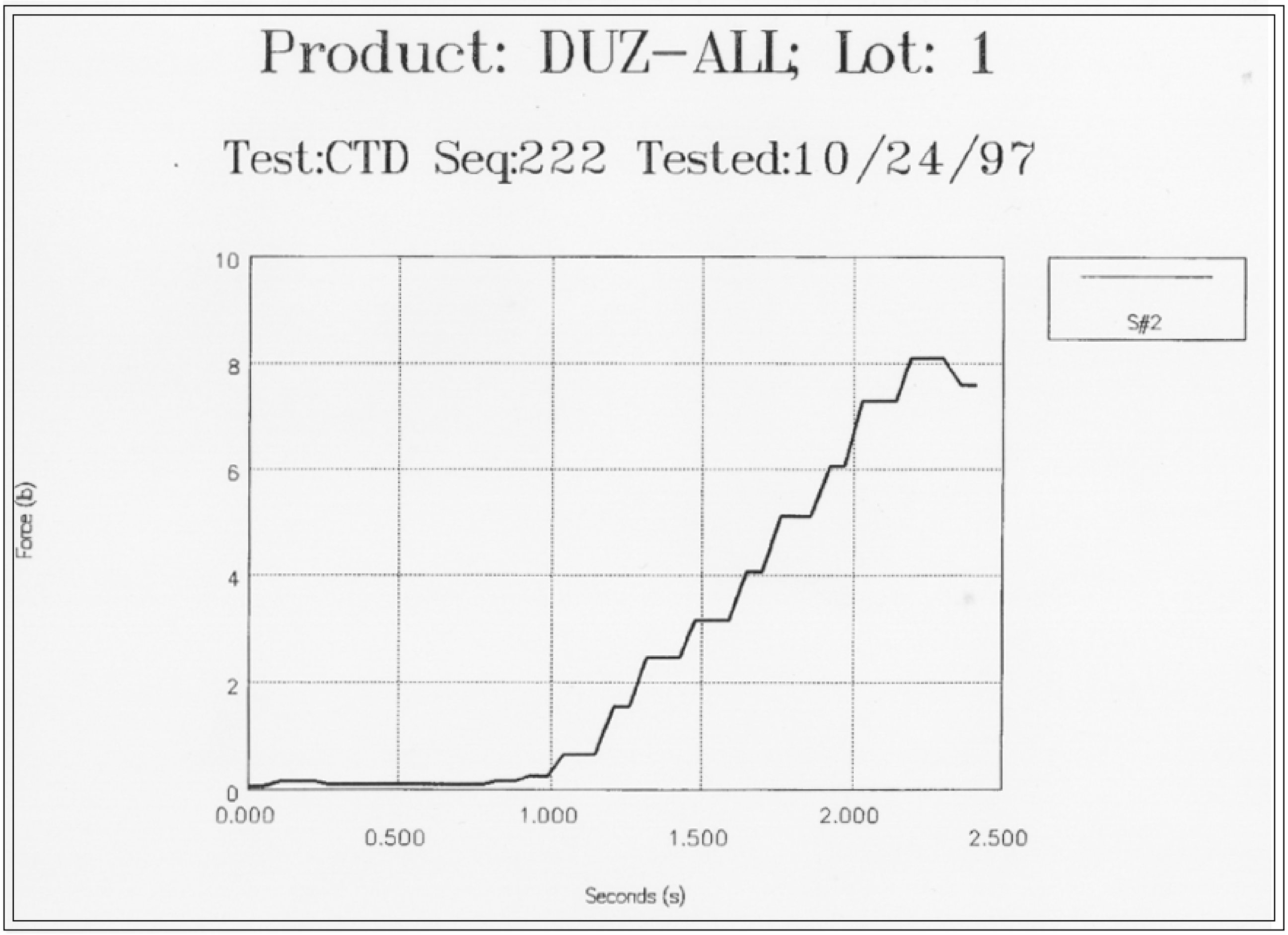
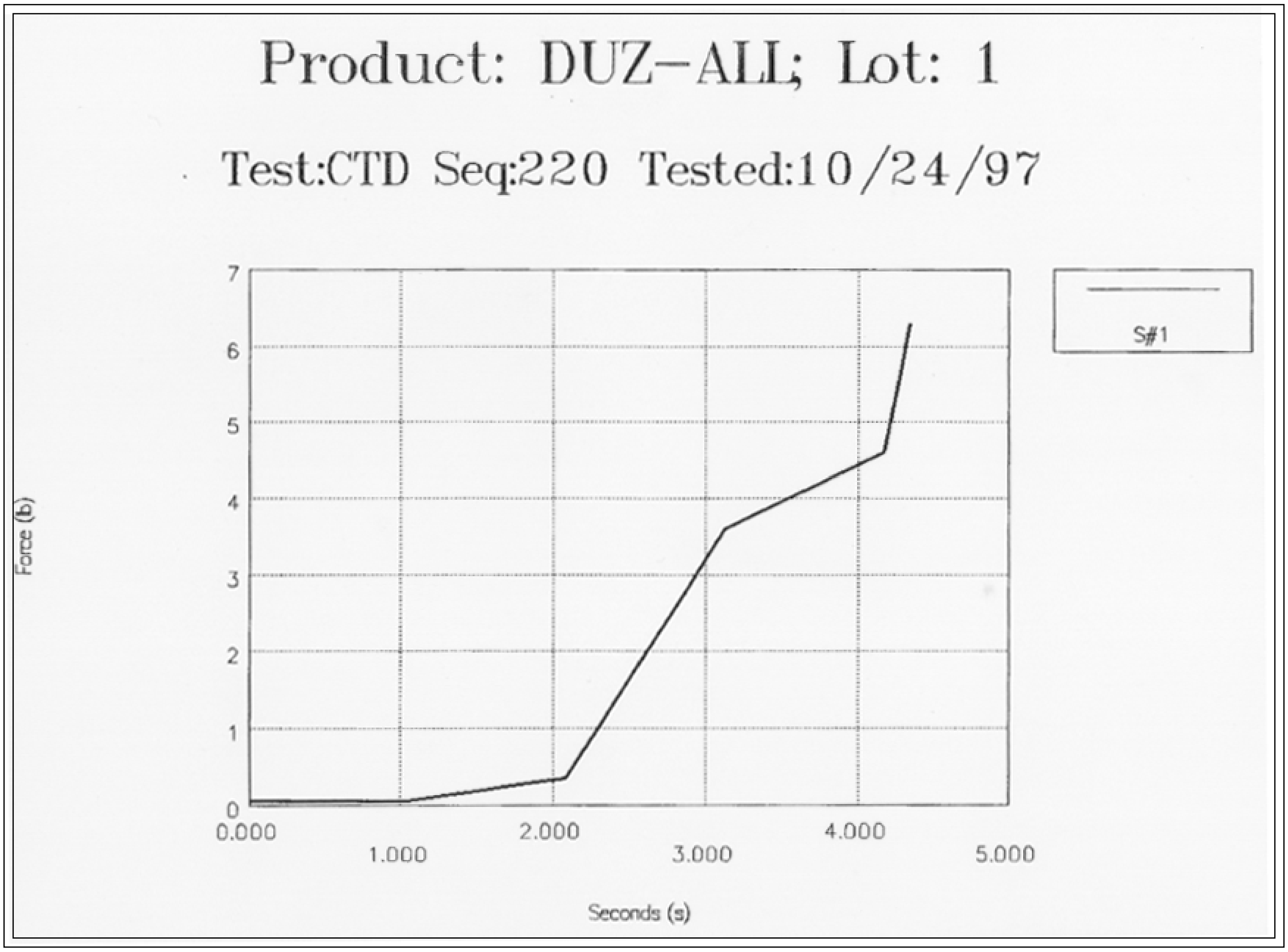
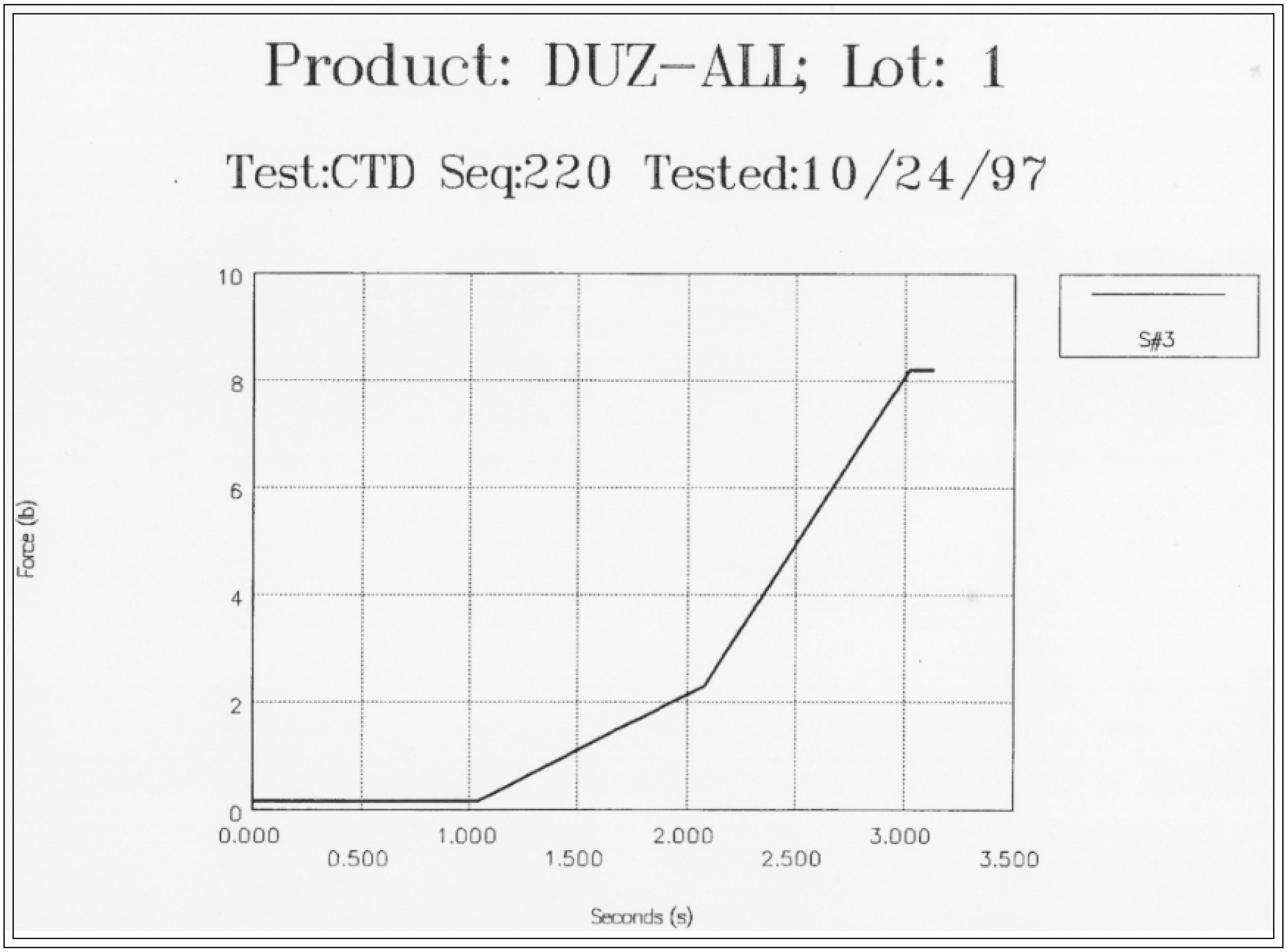
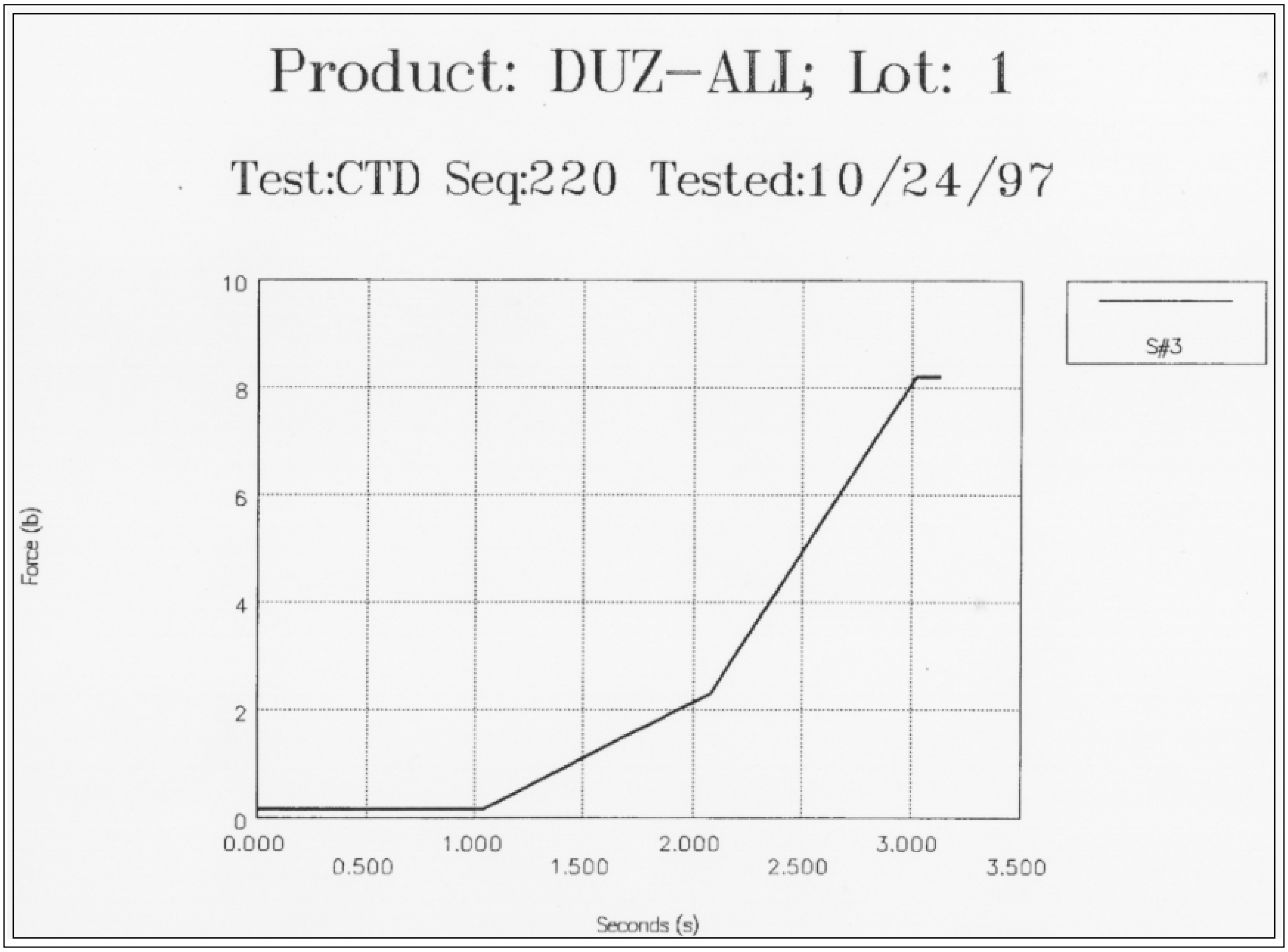
Test:CTD Seq:222 Tested:10/24/97
Force (lb)
10
8
6
4
2
0
–2
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#1


Product: DUZ-ALL; Lot: 1
Test:CTD Seq:222 Tested:10/24/97
10
8
6
4
2
0
Force (lb)
0.000
0.500
1.000
1.500
2.000
2.500
Seconds (s)
S#2


Product: DUZ–ALL; Lot: 1
Test:CTD Seq:220 Tested:10/24/97
Force (lb)
Seconds (s)
0
1
2
3
4
5
6
7
0.000
1.000
2.000
3.000
4.000
5.000
S#1


Product: DUZ-ALL; Lot: 1
Test:CTD Seq:220 Tested:10/24/97
10
8
6
4
2
0
Force (lb)
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
Seconds (s)
S#3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Test:CTD Seq:220 Tested:10/24/97
10
8
6
4
2
0
Force (lb)
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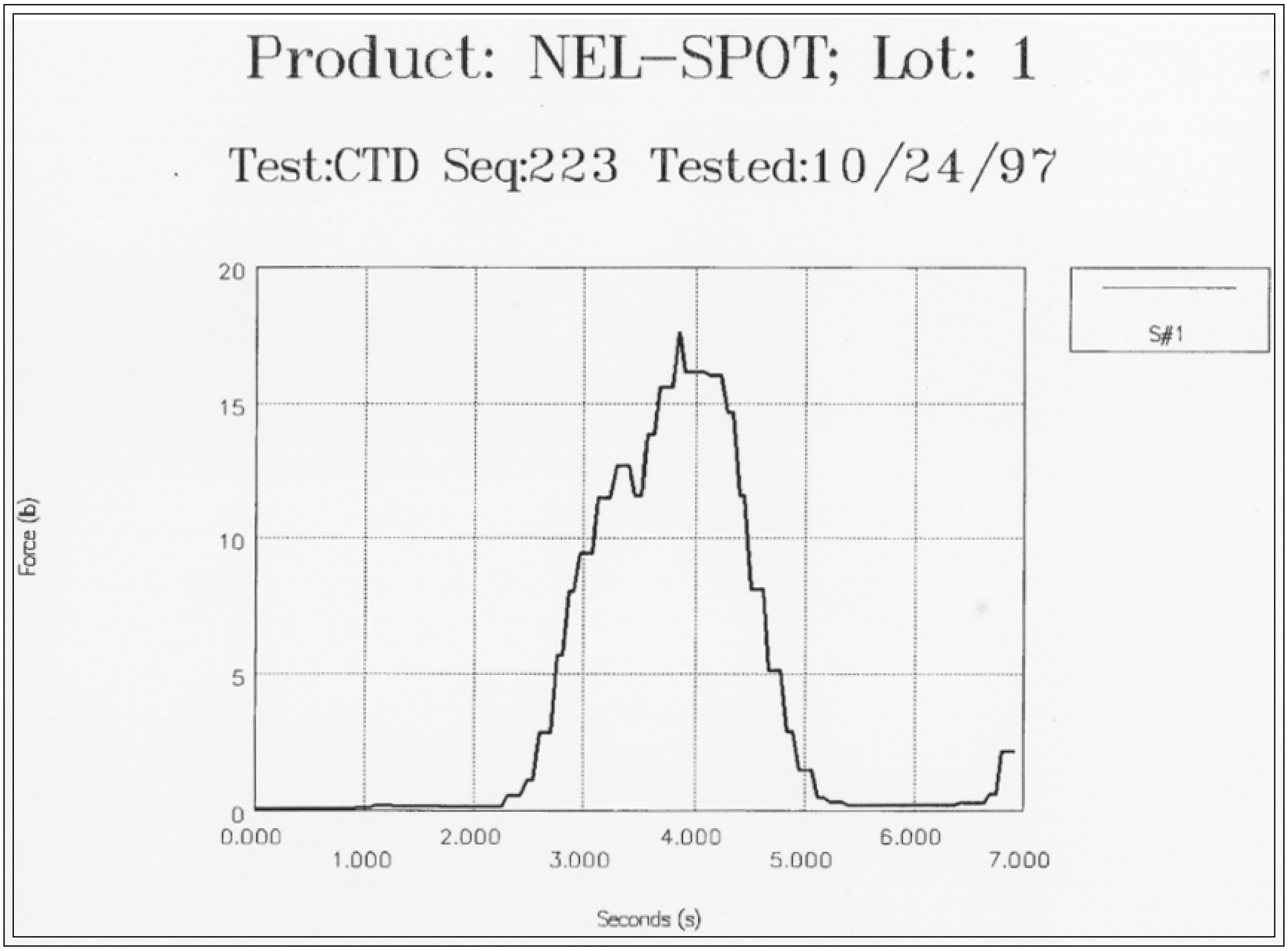
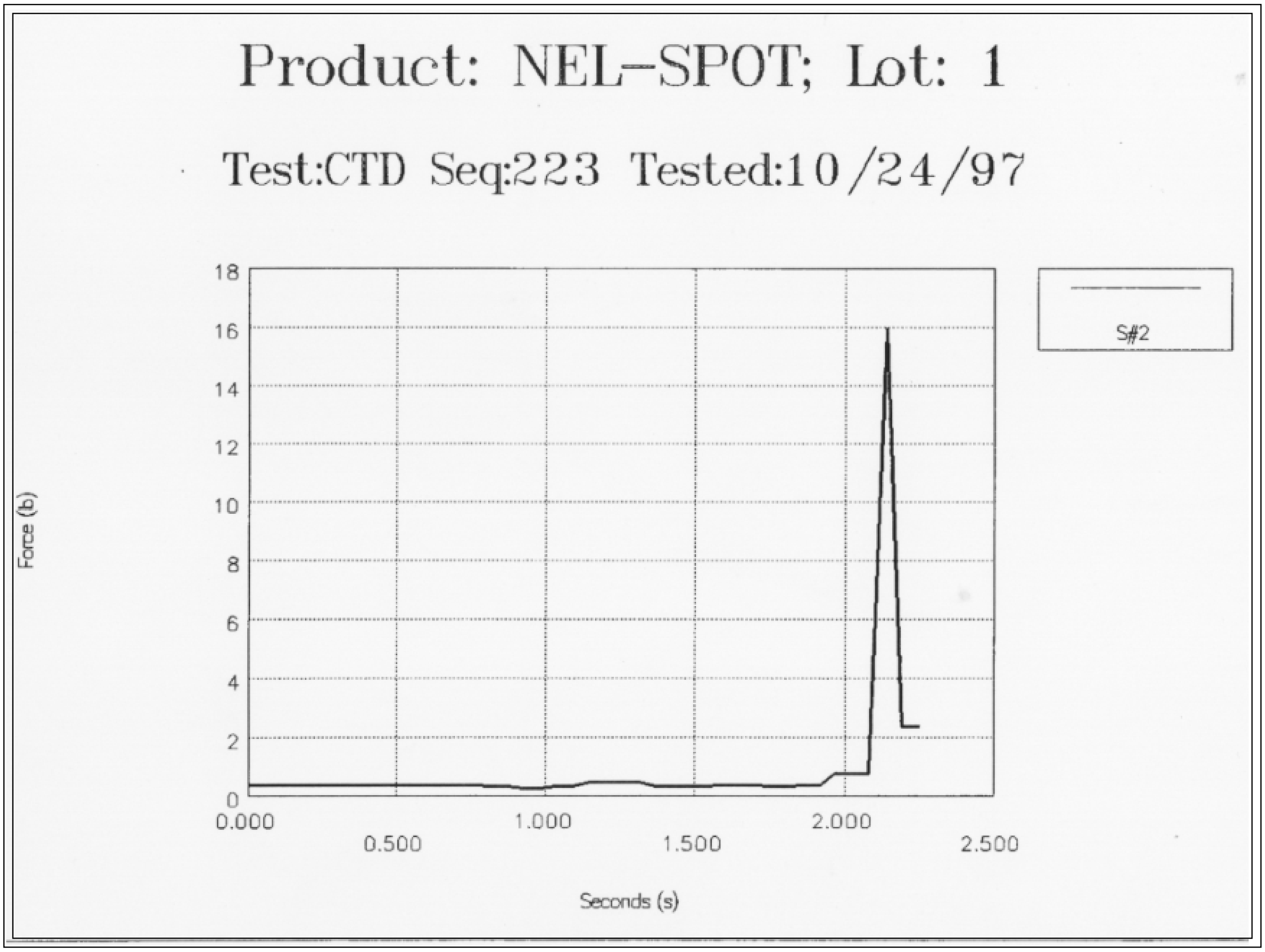
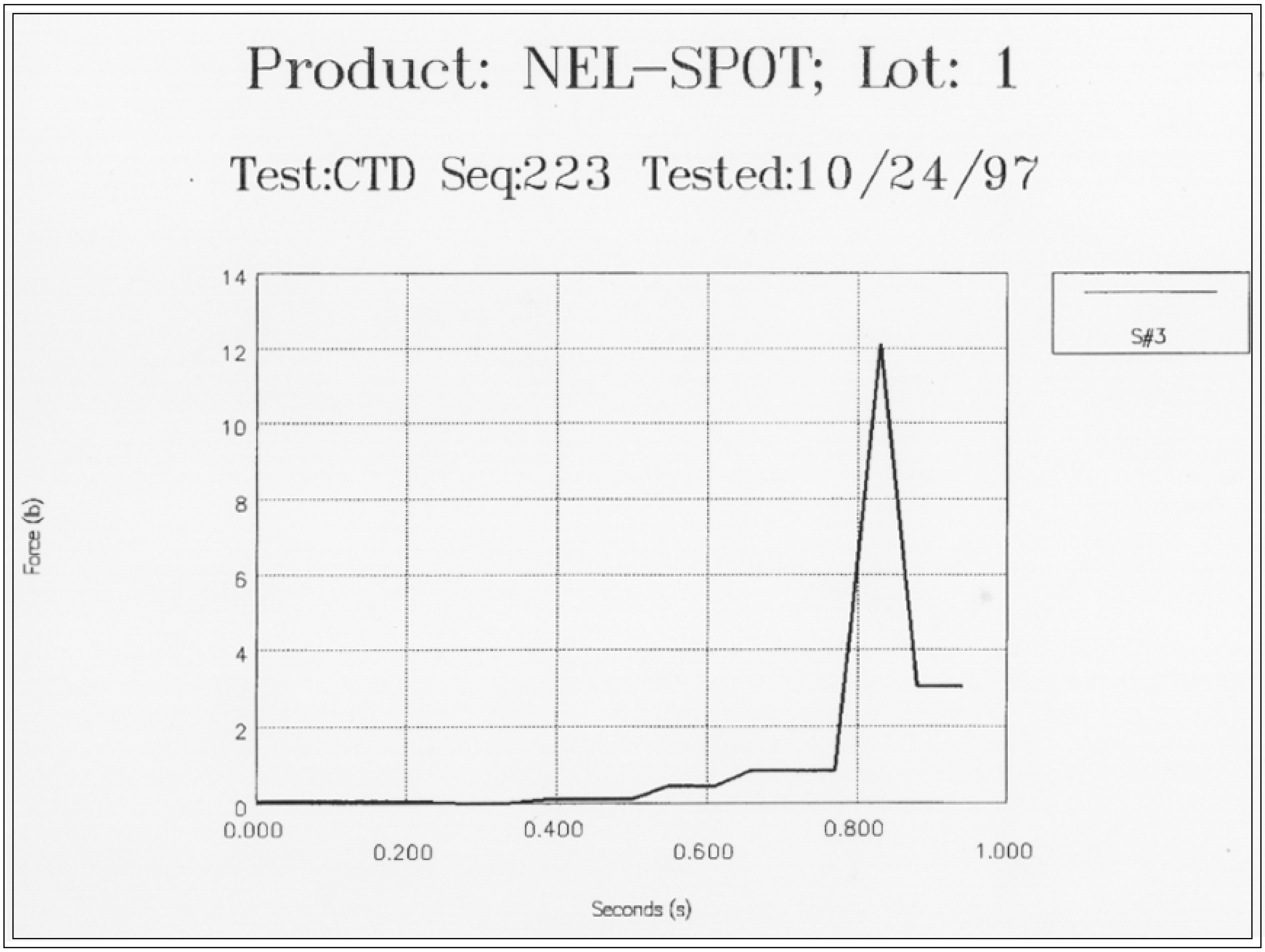
0.500
1.000
1.500
2.000
2.500
3.000
3.500
Seconds (s)
S#3


Product: NEL–SPOT; Lot: 1
Test:CTD Seq:223 Tested:10/24/97
20
15
10
5
0
Force (lb)
0.000
1.000
2.000
3.000
4.000
5.000
6.000
7.000
Seconds (s)
S#1


Product: NEL–SPOT; Lot: 1
Test:CTD Seq:223 Tested:10/24/97
18
16
14
12
10
8
6
4
2
0
Force (lb)
0.000
0.500
1.000
1.500
2.000
2.500
Seconds (s)
S#2



Product: NEL–SPOT; Lot: 1
Test:CTD Seq:223 Tested:10/24/97
Force (lb)
Seconds (s)
S#3
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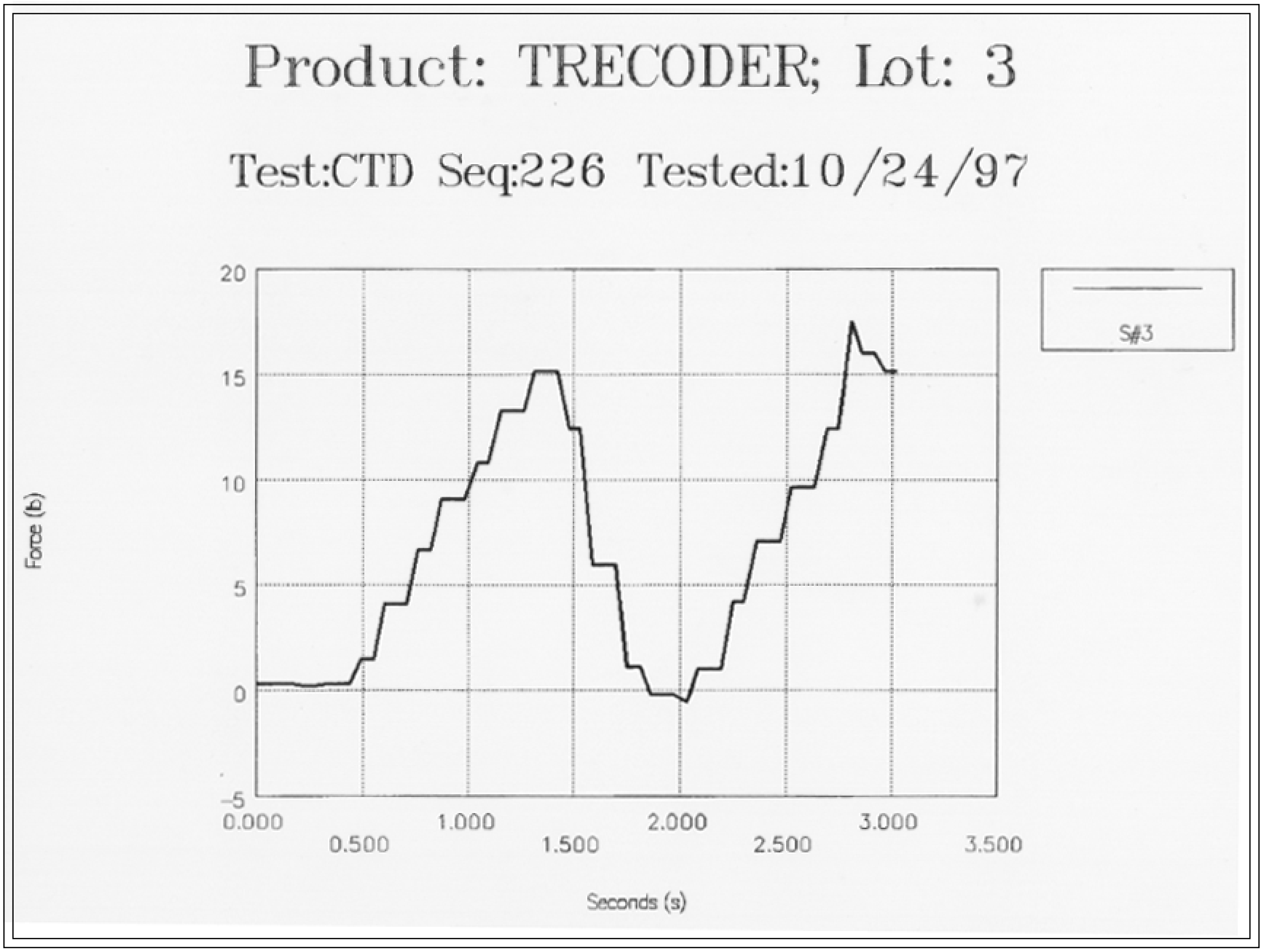
2
4
6
8
10
12
14
0.000
0.200
0.400
0.600
0.800
1.000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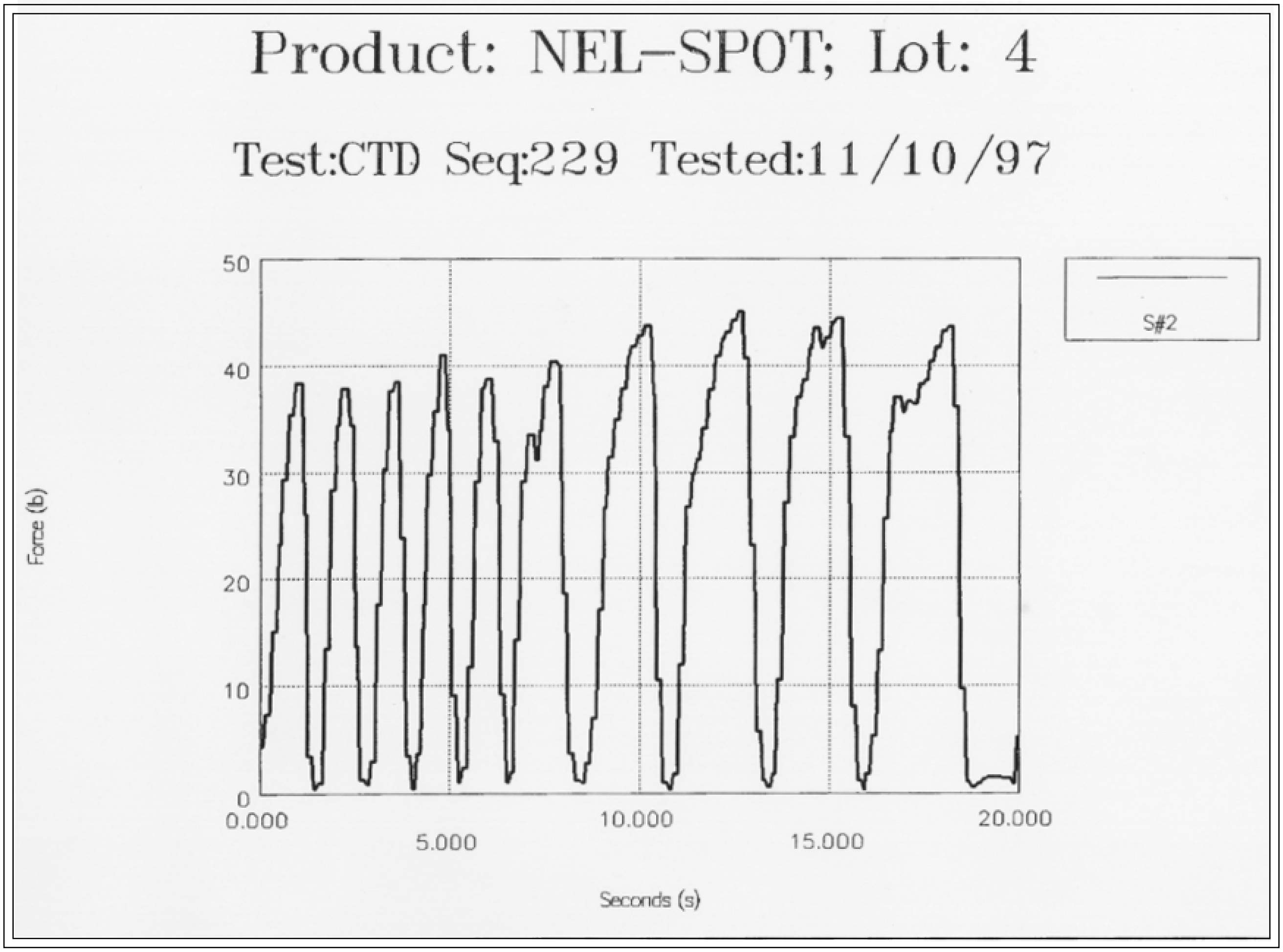
Test:CTD Seq:226 Tested:10/24/97
Force (lb)
20
15
10
5
0
-5
0.000
0.500
1.000
1.500
2.000
2.500
3.000
3.500
Seconds (s)
S#3

APPENDIX 3

Manual Application of Force to Triggers With Type III Tree Marking Paint Force Peak Data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Test:CTD Seq:229 Tested:11/10/97
Force (lb)
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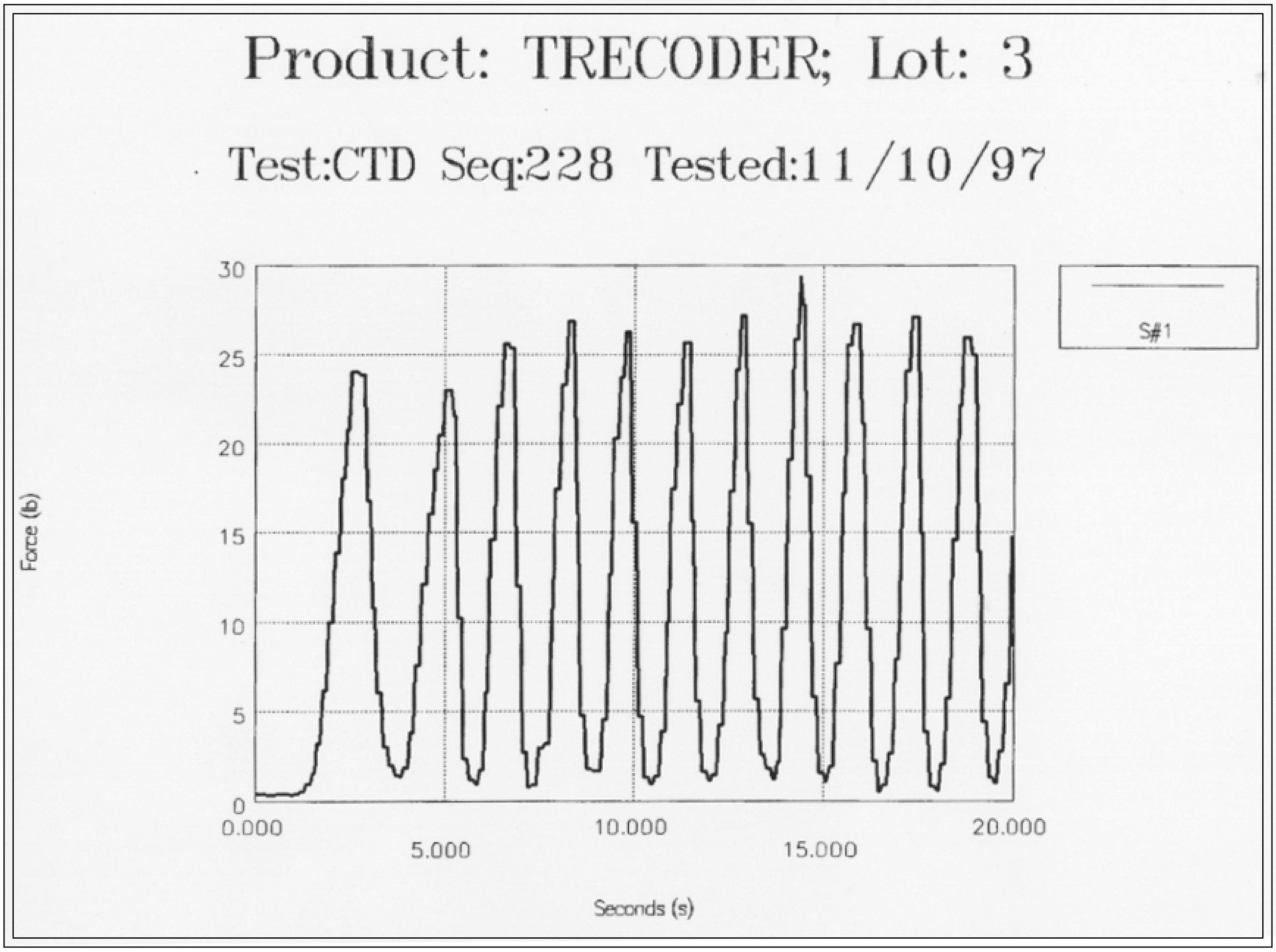
30
20
10
0
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#2


Product: TRECODER; Lot: 3
Test:CTD Seq:228 Tested:11/10/97
30
25
20
15
10
5
0
Force (lb)
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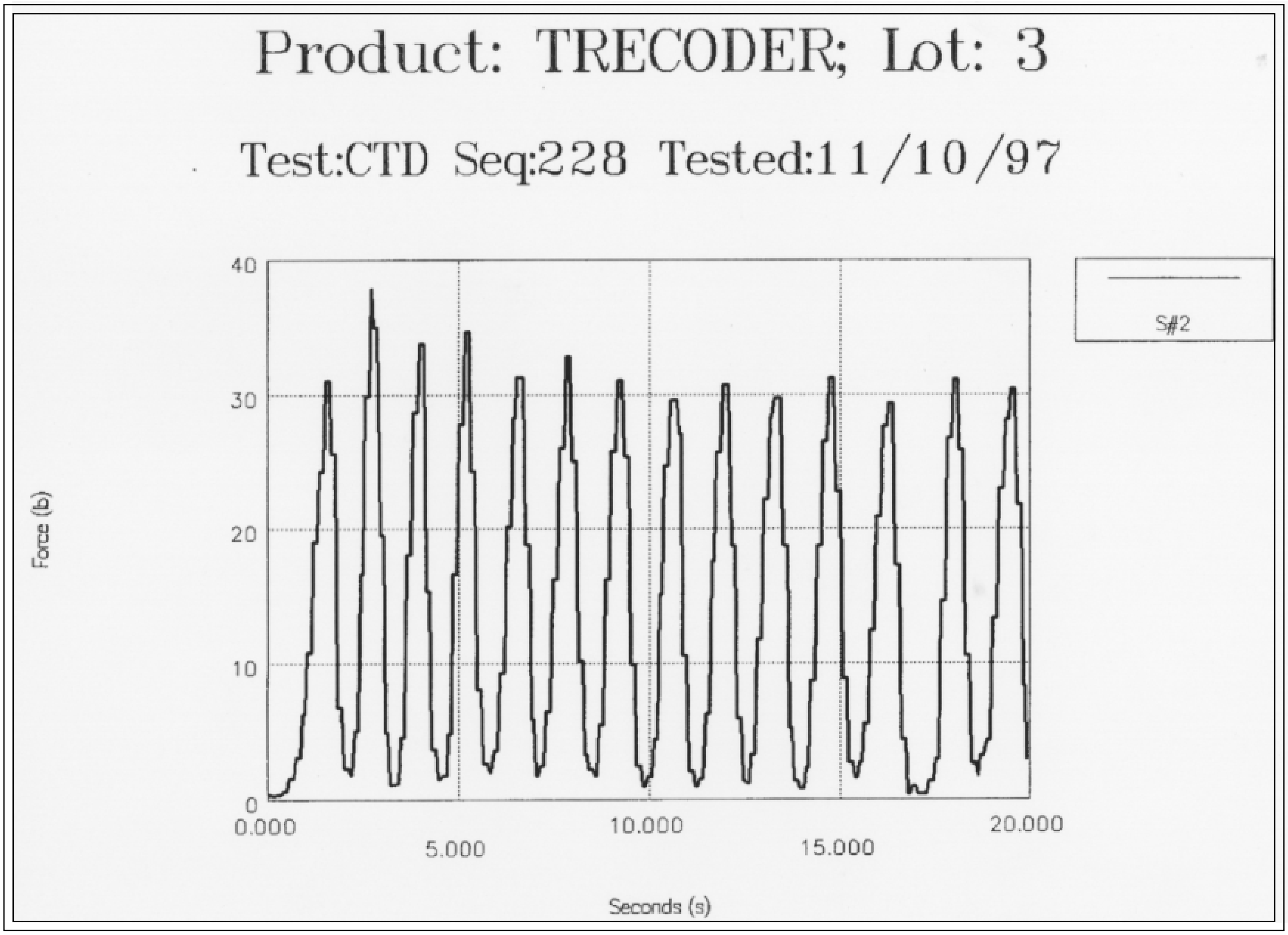
5.000
10.000
15.000
20.000
Seconds (s)
S#1


Product: TRECODER; Lot: 3
Test:CTD Seq:228 Tested:11/10/97
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30
20
10
0
Force (lb)
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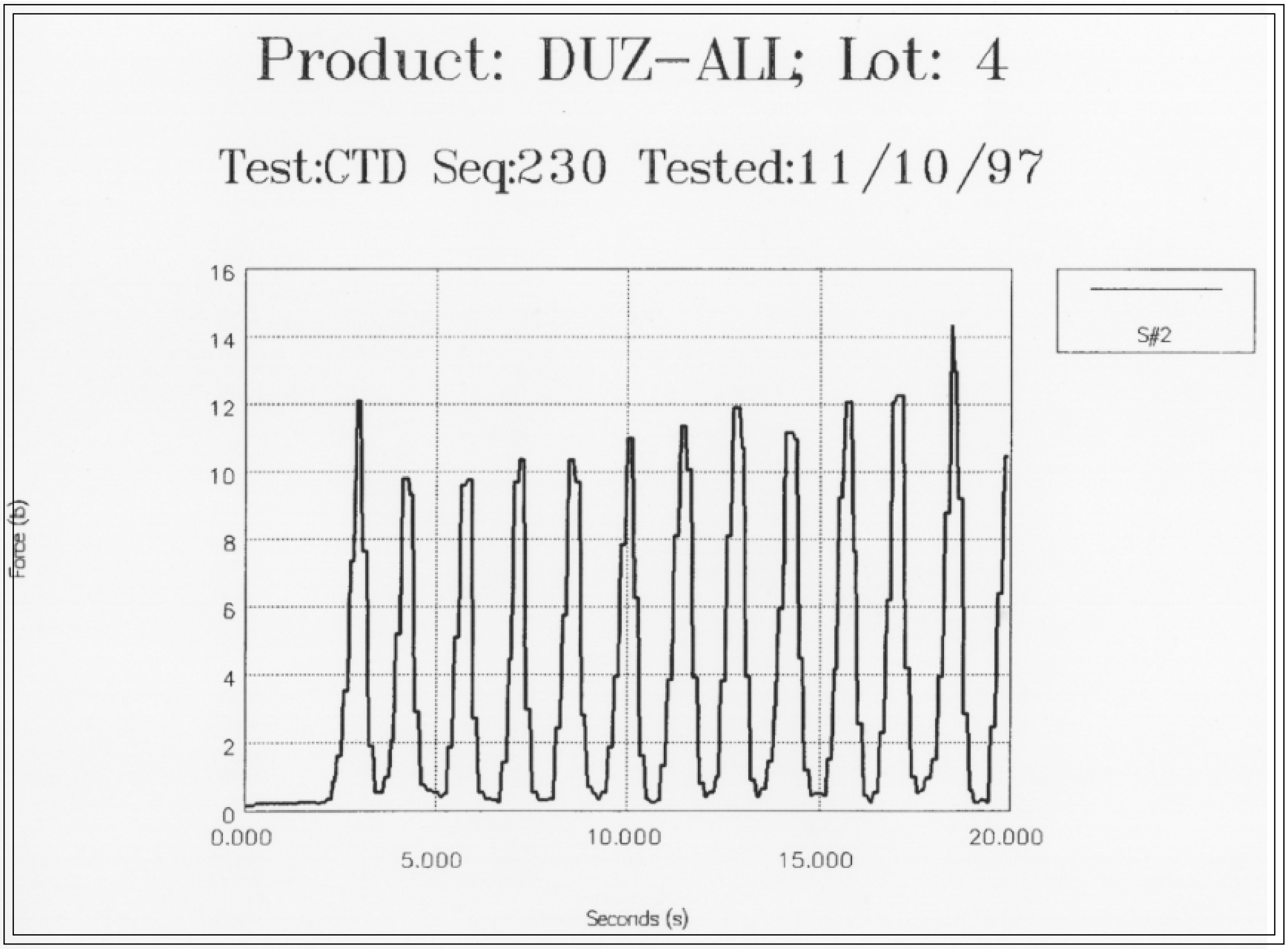
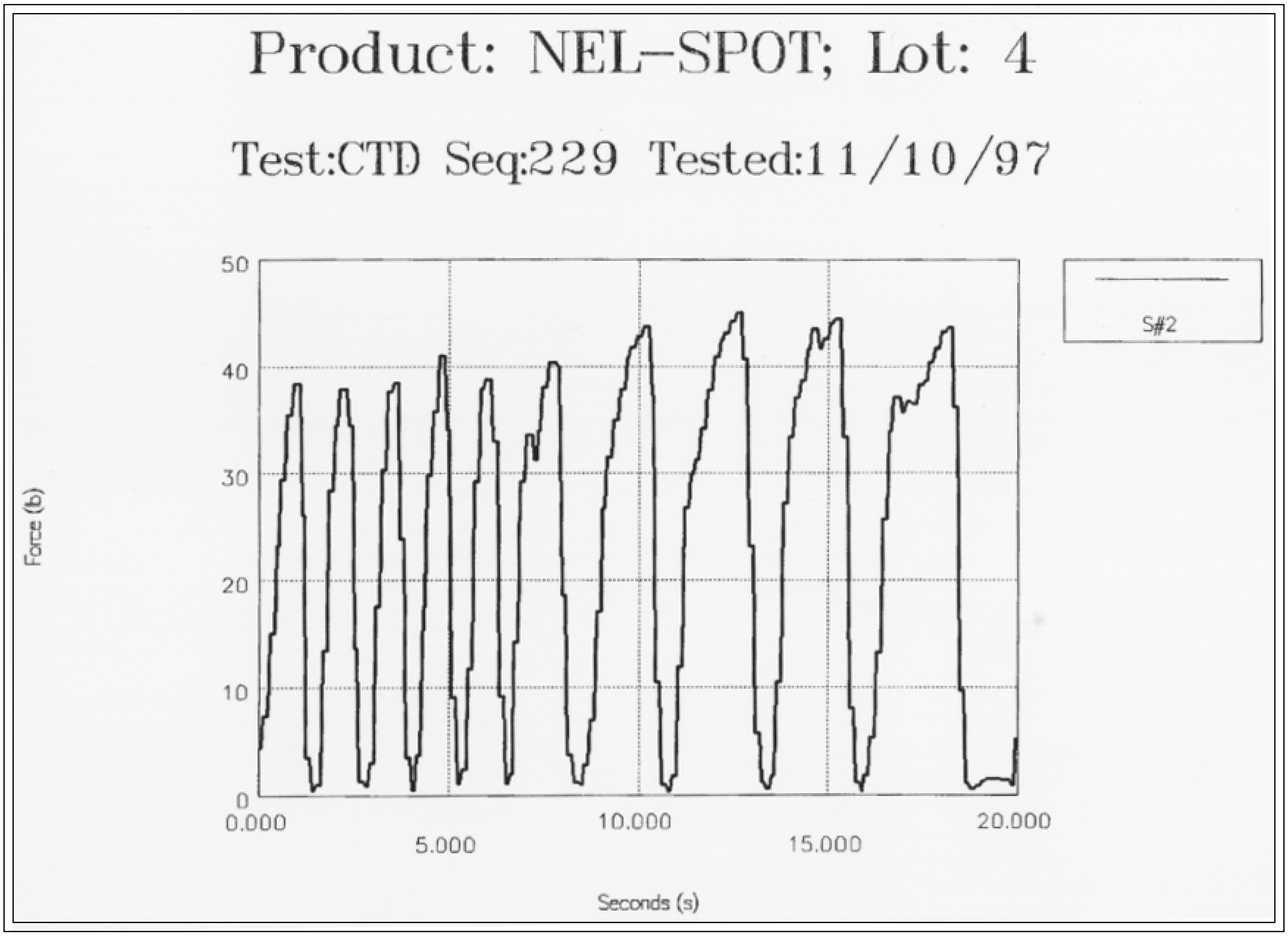
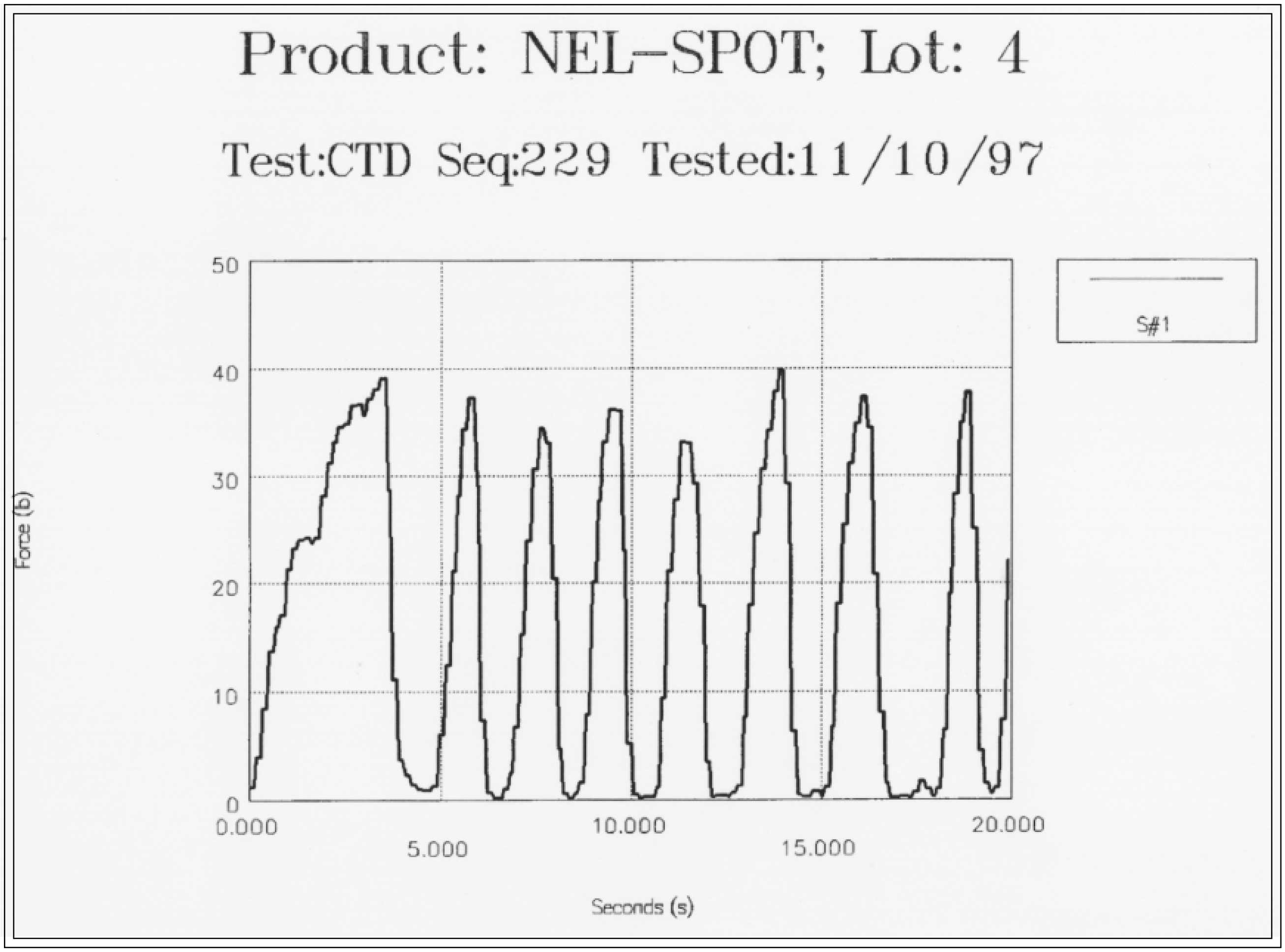
5.000
10.000
15.000
20.000
Seconds (s)
S#2



Product: DUZ-ALL; Lot: 4
Test:CTD Seq:230 Tested:11/10/97
16
14
12
10
8
6
4
2
0
Force (lb)
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#2


Product: NEL–SPOT; Lot: 4
Test:CTD Seq:229 Tested:11/10/97
50
40
30
20
10
0
Force (lb)
0.000
5.000
10.000
15.000
20.000
Seconds (s)
S#2


Product: NEL–SPOT; Lot: 4
Test:CTD Seq:229 Tested:11/10/97
50
40
30
20
10
0
0.000
5.000
10.000
15.000
20.000
Seconds (s)
Force (lb)
S#1